Iowa Barrier Rail Mix Design Development

In 1998, the Iowa DOT did an investigation (MLR-98-01) into slip formed median barrier rail to determine the cause of deterioration in the rails. The rails exhibited severe map cracking, spalling, and leaching. Large voids were typically found and further investigation revealed air contents of less than 2 percent and spacing factors as poor as 0.278 mm (0.011 in).

Barrier rail cores exhibiting large voids

Poor consolidation with Class D mix

Poor workability produces poor performance

The standard mix design for barrier rails is the Iowa Class D mix design. The mix is a 50% coarse, 50% fine aggregate with a high paste content. (See Figure 1) The Class D mix typically yields variable workability in slip formed rails and usually is fairly poor.

In 1999, Kurtis Keifer from Allied Construction contacted the Materials Office to determine if something better could be done for slip form bridge rail than using the Class D mix design. Allied Construction was supplying concrete to Dormark Construction on dual bridges over the railroad on US 18 in Floyd County, near Rudd. The typical problem with the Class D mix design is the contractor must place the mix at ¾" slump or less or the concrete will weep. It is difficult to entrain air in concrete with that low slump and Allied was able to achieve air contents no greater than 5.5%, using AEA at a rate of 25 oz. per cwt.

We decided to investigate the use of well-graded aggregates in conjunction with a reduced cement (paste) content to facilitate placement and air entraining of the concrete. This mix design was labeled as BR. (Figure 1) The BR mix design used the Shilstone principles of well-graded aggregates (see Figures 2-7), this

along with reduced paste gives a more workable mix for slip form, since the concrete is stacking aggregate instead of paste.

The BR mix design utilized the use of ¼" limestone chips to achieve a better gradation. The mix required AEA at a rate of 8 oz. per cwt and achieved 7.4% plastic air content. Slump was increased to 1" for production. Slump was actually increased to 1 ½ ", with no affect on weeping. (See Figure 8)

Dormark and Larry Wishon from Manatts contacted the DOT concerning a retrofit rail on I-35 SB near Ames. A similar mix design was developed with very good results. The mix had a 0.395 w/c ratio with 1.5" slump. 7 and 28 day compressive strengths were 6150 and 7295, respectively.

In fall of 1999, the BR mix design was used on median barrier rail on I-35/80 in Des Moines from Merle Hay Road to 2nd Avenue interchange. Dormark was the contractor and Larry Wishon from Manatt's provided the mix design. The BR mix design allowed better placement characteristics and air entraining capacity than the Class D mix design.

Another development using BR mixes was the use of Class V gravel in a mix on IA 92 bridge rail in Pottawattamie county. The contractor was very impressed with the placement of this mix. The greater ease of placement is primarily due to the use of a rounded aggregate. (Figure 9)

Other recent changes, include the use of ground granulated blast furnace slag in barrier rail on IA 5 in Des Moines. (See Figures 10-11) The use of slag in the mix at approximately 20% replacement and fly ash at 10 to 15% replacement helps produce a very workable BR mix. (See Figure 12) Higher percentage replacement of cement replacement with slag (35%) and fly ash (15%) were used on US 151 at Anamosa. (Figure 13 – 14)

It was noted that the median barrier would allow a higher slump to be placed if the median barrier had a reinforcing cage similar to bridge rail, instead of feeding continuous bars into the mule. (Figure 15 & 16) Design has changed in 2004 to use a reinforcing cage for median barrier rail. (Figure 17 & 18)

Since 2006, after noticeable improvements in workability in slip form barrier and bridge rail, the Shilstone method of well graded aggregate mix design (or BR mix) is now required for all slip form rail. The major workability and placement problems have been reduced since the BR mix has been used. Class D has been eliminated for slip form rail and Class C is now required on fixed form rail.

Figure 1

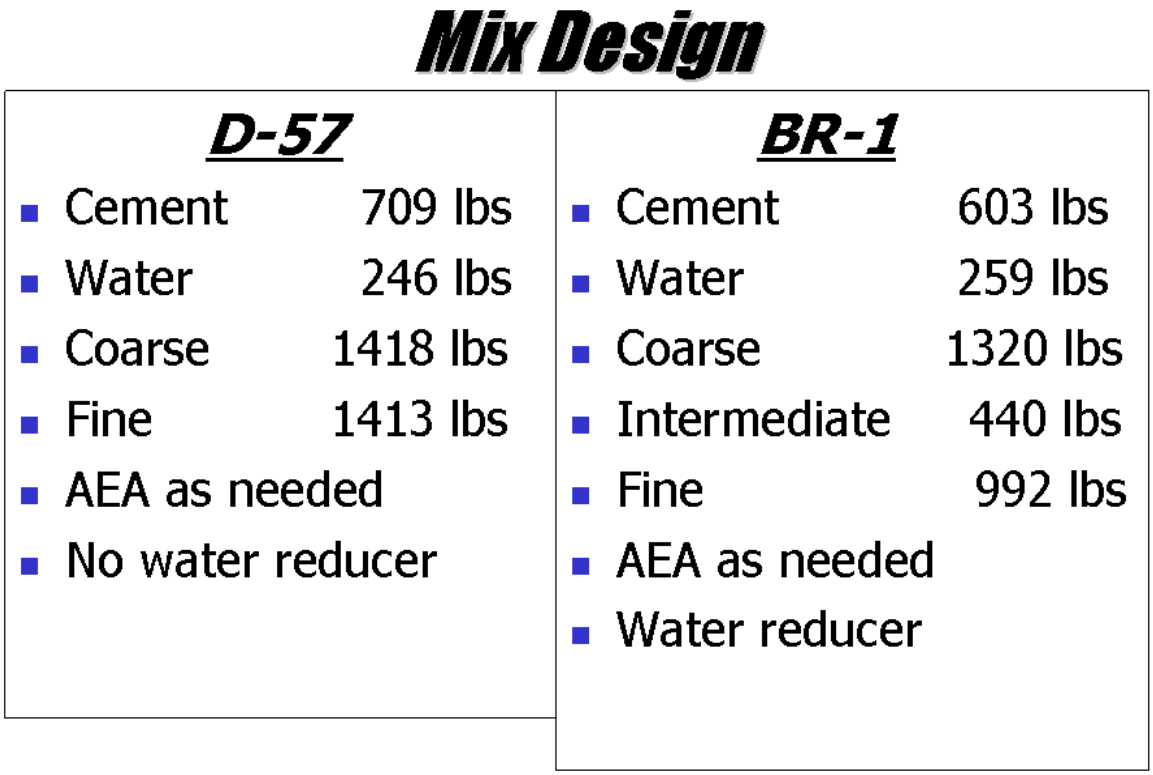
Mix Design
D-57
Cement 709 lbs
Water 246 lbs
Coarse 1418 lbs
Fine 1413 lbs
AEA as needed
No water reducer
BR-1
Cement 603 lbs
Water 259 lbs
Coarse 1320 lbs
Intermediate 440 lbs
Fine 992 lbs
AEA as needed
Water reducer

Figure 2

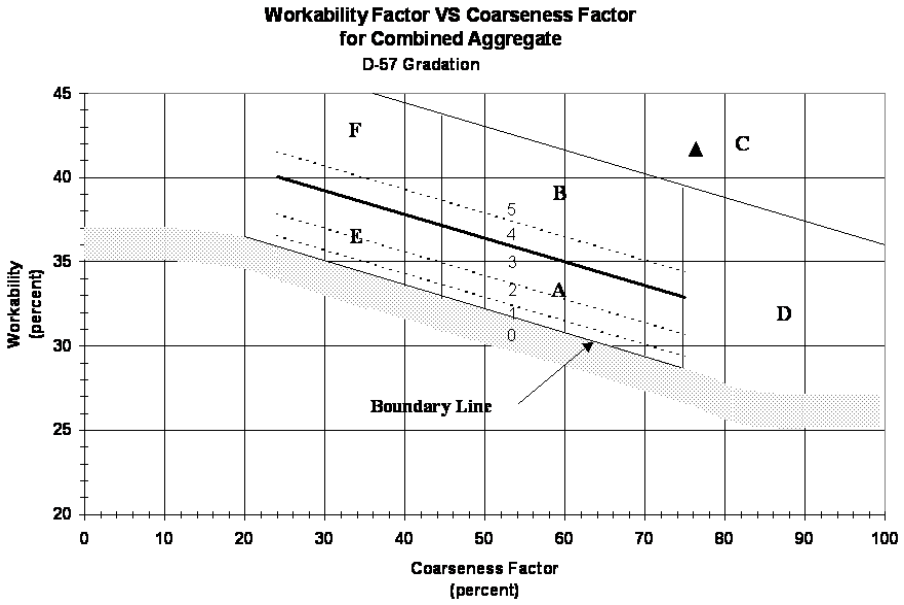

Figure 3

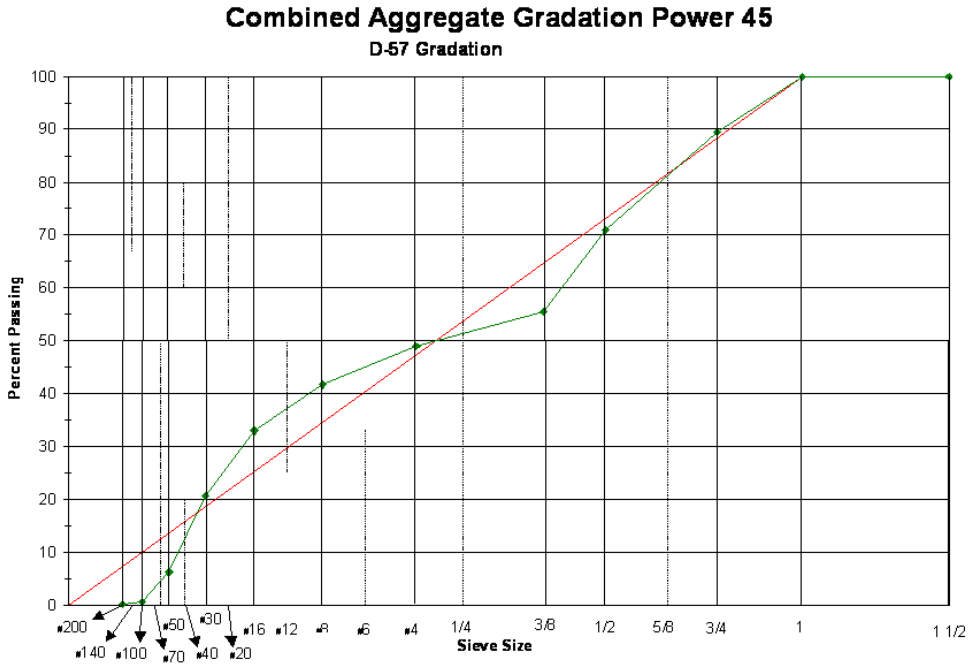

Figure 4

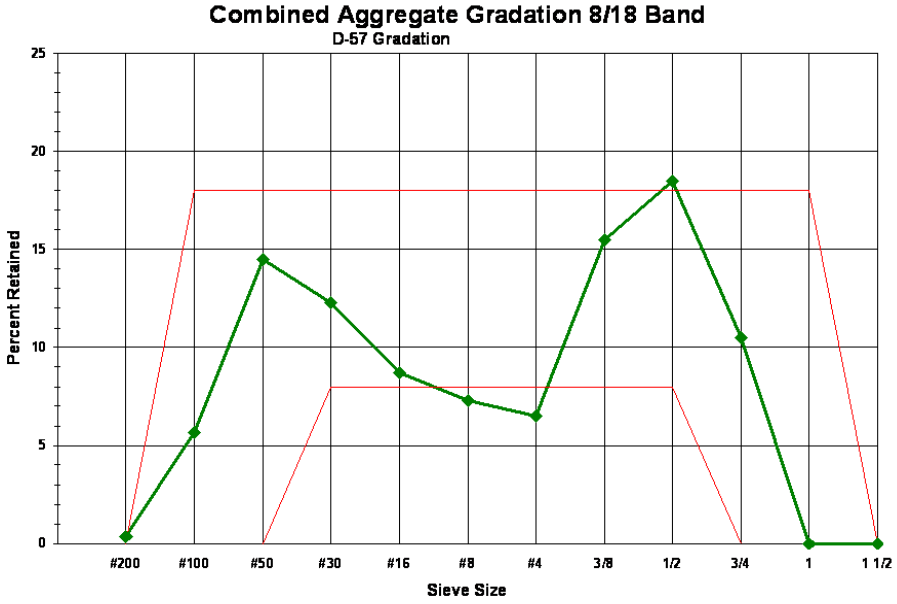

Figure 5

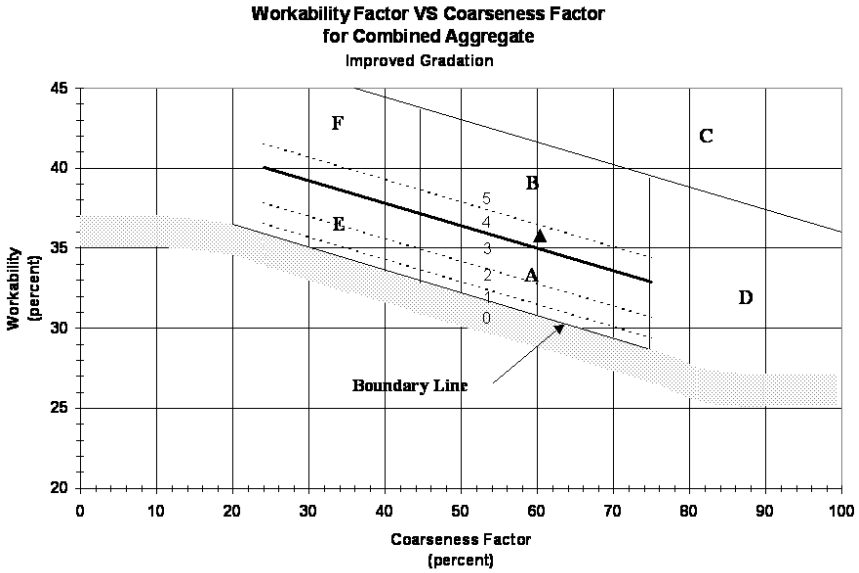

Figure 6

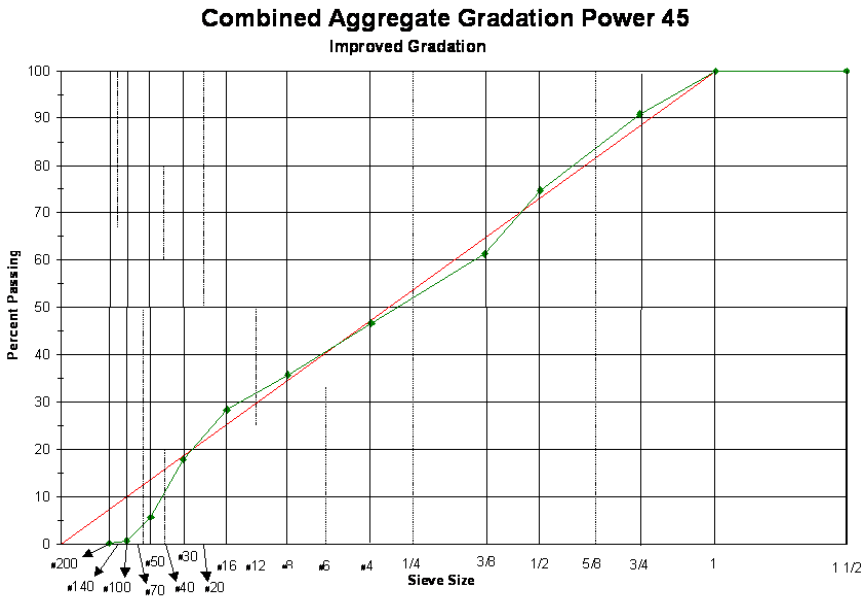

Figure 7

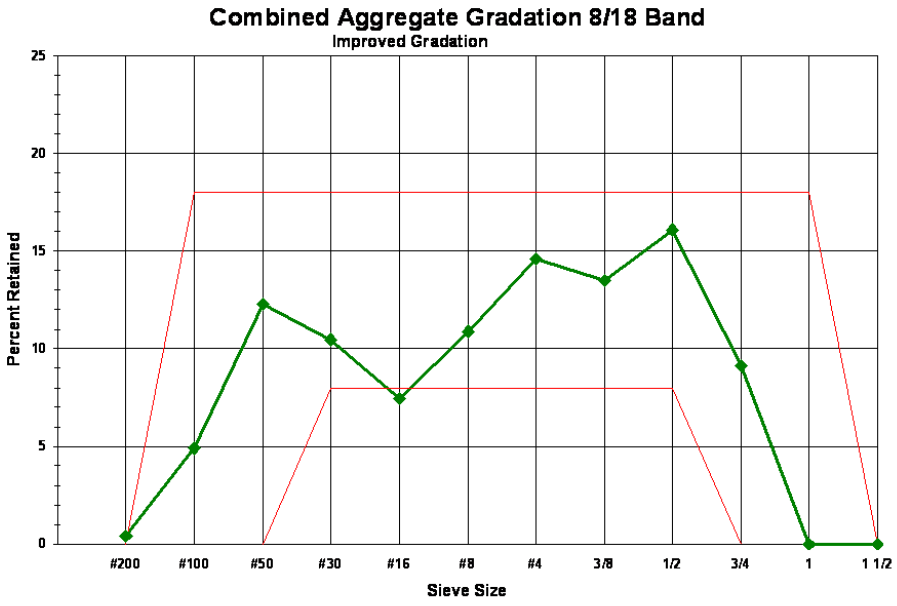

Figure 8

Results

D-57	BR-1

▪ 28 day comp. strength
  ▪ 5750 psi
▪ Cracks per rail
  ▪ 55, 54
▪ AEA @25 oz. -5.5% air
▪ Slump - 0″ to 3/4″
▪ Permeability - 7000
	▪ 28 day comp. Strength
	  ▪ 6800 psi
	▪ Cracks per rail
	  ▪ 26, 11
	▪ AEA @8 oz. - 7.4% air
	▪ Slump - 3/4″ to 1 1/2″
	▪ Permeabililty - 3600

Figure 9 Pott Co Rail

Figure 10 – IA 5 Rail

Figure 11 IA 5 Rail Closeup

Figure 12 IA 5 Mix Design

GENERAL INFORMATION

PROJECT:	0
PROJECT TITLE:	IA 5 over IA 28
MIX TYPE:	RAIL3AGG
MIX NUMBER:	1
DATE:	06/28/00

MATERIALS	*Source*	*Type/Class*	*SPG*	*Percent*	*Percent*
CEMENT:	HUMBOLT KS (MONAF	I/II	3.14		
FLY ASH:	OTTUMWA	C	2.61	10.00	
MINERAL ADMIXTURE:				0.00	
SILICA FUME SLURRY:				0.00	
FINE AGGREGATE:	A77520		2.65	42.00	
COARSE AGGREGATE:	A85006		2.57	52.20	90.00
INTERMEDIATE AGGREGATE:	A85006		2.57	5.80	10.00
AIR ENTRAINING AGENT:	TYPICAL				
RETARDER:					
WATER REDUCER:	TYPICAL				
SUPER WATER REDUCER:					
ACCELERATOR:					
DESIGN W/C(+FLY ASH):	0.39				
DESIGN SLUMP:	1.0 (maximum)				
DESIGN AIR CONTENT:	6.0				

QUANTITIES (absolute volume method)

	Volume ft3 Batch Size 1.0 yd3	Volume ft3 Batch Size 1.0 ft3						Weight lbs Batch Size 1.0 ft3	Weight lbs Batch Size 1.0 yd3
CEMENT:	2.7678	0.1025	X	3.14	X	62.4	=	20.1	542
FLY ASH:	0.3700	0.0137	X	2.61	X	62.4	=	2.2	60
MINERAL ADMIXTURE:	0.0000	0.0000						0.0	0
SILICA FUME SLURRY:	0.0000	0.0000						0.0	0
WATER:	3.7660	0.1395	X	1.00	X	62.4	=	8.7	235
FINE AGGREGATE:	7.7600	0.2874	X	2.65	X	62.4	=	47.5	1283
COARSE AGGREGATE:	9.6446	0.3572	X	2.57	X	62.4	=	57.3	1547
INTERMEDIATE AGGREGATE:	1.0716	0.0397	X	2.57	X	62.4	=	6.4	172
AIR:	1.6200	0.0600	X	0.00	X	62.4	=	0.0	0
Summation	**27.0000**	**1.0000**						**142.2**	**3839**
Paste Content	**25.6**								
Mortar Content (abs vol)	**60.3**								
Mortar Content (% pass)	**56.6**								

CHEMICAL ADMIXTURES

	Rate oz/100 lbs cementitious							Rate ml Batch Size 1.0 ft3	Rate ml Batch Size 1.0 yd3
AIR ENTRAINING AGENT:	NORMAL DOSAGE	22.32	X	######	X	29.57	=	#VALUE!	#VALUE!
RETARDER:									
WATER REDUCER:	1/2 TO FULL DOSAGE	22.32	X	######	X	29.57	=	#VALUE!	#VALUE!
SUPER WATER REDUCER:									
ACCELERATOR:									

Figure 13 US 151 Rail

Figure 14 US 151 Rail Closeup

Figure 15 Design Standard Median Rail until 2004

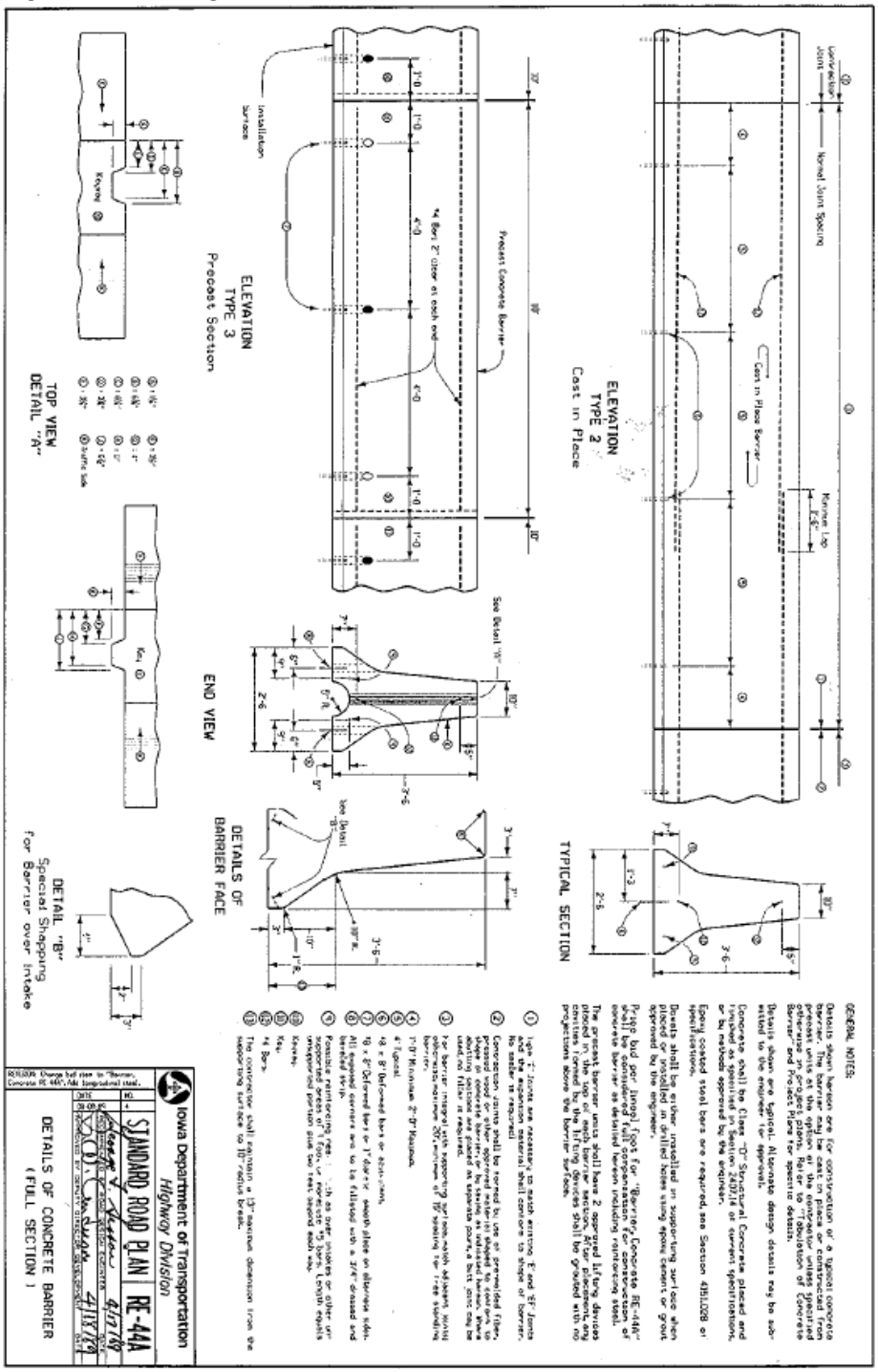

Figure 16 Rail machine with steel inserted (old design)

Figure 17 Design Standard Median Rail 2004

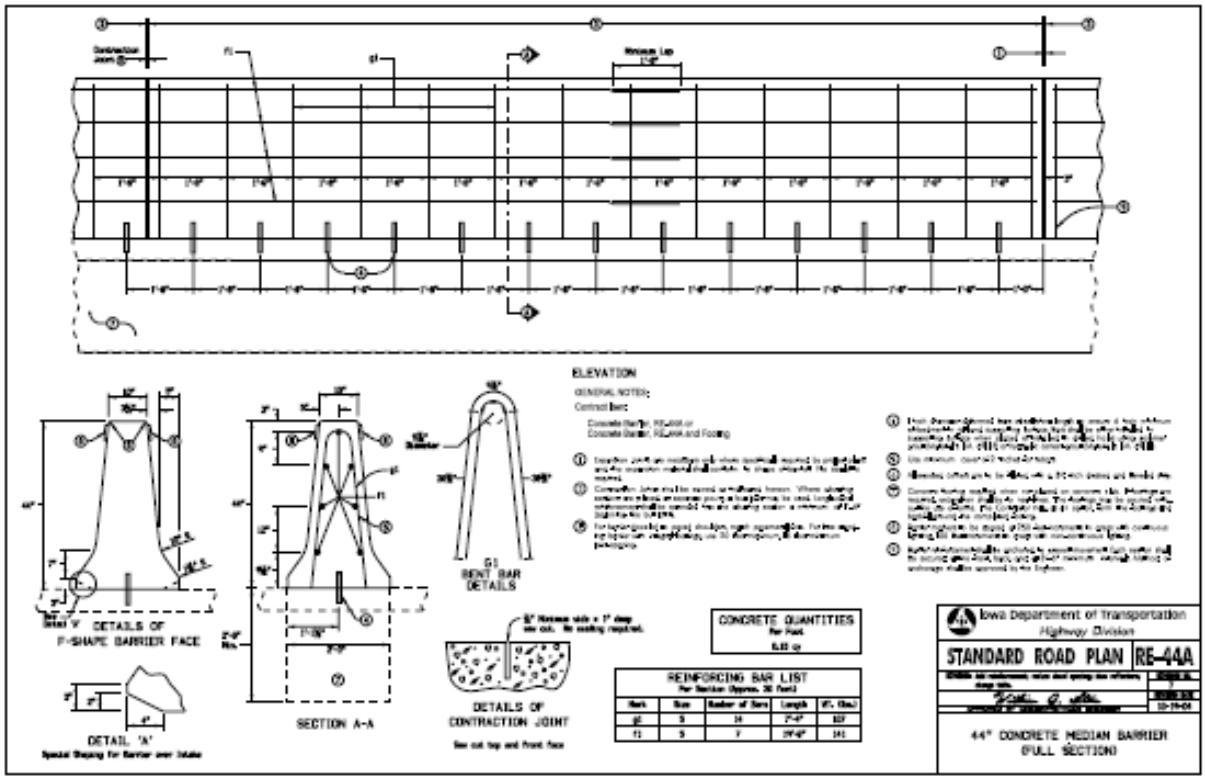

Figure 18 – Median rail cage 2004